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THE AMERICAN

METEOROLOGICAL JOURNAL.

VOL. III. ANN ARBOR, MAY, 1886. NO. 1.

CURRENT NOTES.

THE BERLIN BRANCH of the German Meteorological Society, still retains its activity, and its preeminence in point of view of membership. We have its third annual report before us, edited by Dr. Hellmann who still continues as secretary. Its membership is now 101 and the list contains several very eminent names. As an appendix Dr. Hellmann adds a few pages as a report on the conditions of the study of the precipitation in and about Berlin.

BELGIAN PRIZE QUESTION.—The Belgian Academy proposes the following question for competitive essays:—"Desired, new spectroscopic researches to ascertain if the sun contains or not the essential constituent principles of organic compounds." The prize is a medal worth about 800 francs. The memoirs must be sent to the perpetual secretary of the Academy (at Brussels) before August 1, 1887, and may be written in French, Flemish or Latin.

CHANGES IN THE CONNECTICUT RIVER.—Dr. Wm. C. Prime writes in the *Journal of Commerce*: "The Connecticut river, given over to the timber-drivers, has become a canal. Reefs are blasted out. Bulkheads are built to turn the current into the central channels. The melting snows are no longer held back in the spongy mosses of the forests, and the spring rains are hurried swiftly down in freshets, which destroy property in the lower

country. The freshets are utilized to bring down every spring the timber from the thousands of acres, where no pine wood will ever grow again. The summer comes, hot and dry, with low water in the rivers, which were formerly full all the summer from the slow drain out of the dark shades in the upper country. The natural reservoirs, which thus gave out slowly their reservoirs of water, are gone, and all the water comes down with a rush after every rain. Manufacturing companies everywhere have found it necessary to make artificial reservoirs to take the place of the lost natural reservoirs. Hills that were once forest-covered are bleak masses of rock, growing drier year by year. If there was ever an instance of killing the goose that lays golden eggs, it is in this method of treating our northern forests. In hundreds of valleys where water was abundant in former years, the water line in the ground is now below the reach of ordinary wells. The tendency is toward that condition which in a century or two will compel a resort to irrigation for ordinary agricultural purposes."

THE CLIMATIC TREATMENT OF DISEASE—In an article read before the American Academy of Medicine, New York, October 29, 1885, and revised for the Sanitarian by the author, Dr. Henry O. Marcy, special thought is given to the subject of the curative influence of climate upon consumption. Dr. Marcy says: "Granting that consumption is dependent upon the development of a bacillus within the lung, what may we legitimately expect from climate for its destruction or expulsion? Its propagation so far as we now know, is dependent upon a proper soil, which means the furnishing of proper nutriment in the form of albuminoids, a continuous temperature, and a proper amount of moisture. These supplied, the bacilli reproduce abundantly externally to the individual, and that they do not in any manner lose their pathogenic qualities is shown by their ready reproduction and development, following innoculation, causing the death of healthy animals."

"Do climatic changes modify these factors? Much has been claimed for and written upon the advantages of a dry climate

in consumption. There are other reasons why this may give benefit, but I suppose that no one will contend that the fluids in the tissues of the lungs are materially lessened thereby, or that, while life continues, these can by any manner of means be so diminished as to prevent bacillary development. The heat-point for the bacillary growth must be maintained so long as the individual exists, for its reduction to a point to interfere with its development, must be incompatible with the conditions possible for the maintenance of the life of the individual. Given the depreciation of the vitality of the tissues locally, and that the albuminoids requisite to furnish food for the unwelcome tenants continue, and we safely infer, from what we now know, that an aseptic atmosphere, however dry or rarified, cannot alone furnish the factors of a cure."

"We should," says Dr. Marcy, "look out for aid to the infected individual from climatic change, not in the breathing of an 'anti-bacillary atmosphere,' but in the placing of the patient in surroundings suitable, if possible, to strengthen his weakened vital resisting powers, and re-enforce his tissue development, so that it may be superior to the attack of the would-be destroyer; and although we do not know all the conditions requisite for counteracting the growth of morbiferous bacilli, we are assured that healthy tissues and blood imperfectly furnish the required pabulum." N.

COLONIES AND COLONISTS.—It has been acutely suggested lately that the two do not necessarily go together. The English usually establish colonies with colonists; witness Canada and Australia, though in their case India forms an exception where of a population of 250,000,000 there are only 50,000 Europeans. France usually establishes colonies without colonists. In Algiers, as long as it has been in the possession of France, as healthy as it is, and as near the mother country as it is, there are now only about 300,000 Frenchmen, not more than half the number that annually embark from Europe for America. Madagascar is notably a colony without colonists, and so is Tonquin. On the other hand, Germany so far has practiced the method of

colonists without colonies. No one would guess from the map that southern Russia is penetrated and occupied by German colonists, but so it is. They have not taken their political system with them and are not therefore in any proper political sense colonists. Buenos Ayres, Brazil and, for that matter, all South America are penetrated by such German colonists without colonies.

Of these methods of colonization, the first is a marked success and the second a marked failure. That is to be expected, but what are we to expect of the third method? Whatever expectations might have been formed of it, it is a success. The German colonists are generally prosperous and happy, and, without general political system of their own, impress their mark distinctly on the political system of their adoption.

Colonization is a matter of climate, but by no means so largely as is generally believed. The Caucasian, if prudent, can stand any climate not actually poisonous with miasma, and can adapt himself so completely as to lead a happy existence in Iceland or in Sumatra. Colonization is more largely a matter of race-spirit. Some races are natural colonizers, others not.

A Dry Quicksand.—In the southwestern corner of the desert of southern Arabia, north of the western end of Hadramaut, and approached from the little village of Sawa, is a very remarkable spot described by Wrede from his visit in 1843, whose description is reproduced in a recent number of the *Revue coloniale internationale*. There are here, in the waste of yellow sand, several spots covered by a grayish white dust, which swallow up every object thrown into them. One of these spots, described by Wrede, is about two miles long and a little less in breadth. It sinks gradually toward the middle and is apparently due to the work of the wind. Wrede approached it with the greatest care and sounded it with his staff. The edge is stony and falls away suddenly. When the staff was thrust into the fine material beyond the edge, almost no resistance was felt and it was as if the staff had been thrust into water. When it was passed through the fine dust lengthwise the resistance was al-

most imperceptible. A stone of two pounds weight or more was fastened to a cord sixty fathoms long and thrown in as far as possible. It sank at once and with increasing velocity so that at the end of five minutes the end of the cord had disappeared. The presence of Bedouins prevented any more observations. The natives believe that great treasures are buried here and are watched over by genii who pull down into the depths the unwary treasure-seeker.

River-beds in Lake Bottoms.—The investigations of the Swiss typographical bureau have brought to light the fact that the Rhone and the Rhine in passing through the Lakes Constance and Leman preserve, more or less completely, their beds, so that we have subaqueous rivers. The rivers are both Alpine and their cold waters, naturally heavy, are loaded with glacial detritus. The ravine of the Rhine has been followed for two and one-half miles from it mouth to a depth of over 410 feet. In profile it is of great size, measuring up to 230 feet in depth, and nearly 2000 feet across. The subaqueous ravine of the Rhone has been followed about four miles; it is from a quarter to a half mile broad and it is yet 33 feet deep where it is from 650 to 750 feet below the surface. These ravines consist of a furrow hollowed in the general talus of the sublacustrine delta, with lateral walls on each side. The course is not rectilinear, but more or less curved, and in Lake Leman it is in general parallel to the banks of the lake. Analogous ravines are found at the mouths of old, but now dry, beds of the Rhine and Rhone.

It seems evident that the current of the rivers continues under the level of the lakes, and that with sufficient force to dig out for itself a bed. The lateral walls must be due to deposit of suspended mud along the lines where the river current is deadened by contact with the standing waters of the lake. The phenomena are due to the superior weight of the glacial river water, and as this is in part due to its temperature, and the subaqueous river must differ in summer and winter. If the sublacustrine stream and its deposits be viewed as a delta, as can properly be done, we have in them a new form of delta, one due

to heavier water pouring into lighter. The sorts of deltas will then be two. 1.—Those of lighter river waters pouring into the heavier salt water; (the usual marine deltas as those of the Orinoco, Mississippi, and Nile). 2.—Those of heavier glacial rivers pouring into warmer fresh water lakes, as those described above. Many others of these deltas undoubtedly exist.

The account of those of the Rhine and Rhone was published in the *Comptes rendus*, but the above abstract was drawn from *Ciel et terre*.

THE CANADIAN METEOROLOGICAL SERVICE.—The receipt of the annual report of this excellent service gives occasion to call attention to its work. The report is the thirteenth annual one and is for 1883. Charles Carpmael Esq. is the superintendent and the head quarters are at Toronto. The number of stations reporting is quite large and they are well scattered over the vast territory occupied. There were ten in British Columbia and nine in the Northwest Territory. The Canadian Pacific also co-operates with the service by establishing numerous stations along its line.

The most of the 170 pages of this report are taken up with monthly and five-day means from the individual stations. Four maps give geographically the precipitation for the four quarters of the year for Ontario, and two give the same data for the second and third quarters for Manitoba.

A notable feature of the reports of this service (both the annual and the monthly) are their compactness. The expenses are not given in the report, but it is noted that both Ontario and Manitoba have come to the assistance of the general service. It is a pity that so important a service, so well administered, should suffer from the lack of funds.

A VALUABLE ENTERPRISE.—Mr. S. S. Bassler has had the happy idea of publishing weekly the tri-daily weather maps for the United States, east of the Rocky Mountains. His first number appeared March 8, and is a small folio entitled "The Weather Journal." It is good in form and manner and, in the

case of the writer at least, "fills a long felt want." Its cost is only one dollar and a half per year, and we heartily wish it a great popularity. It will be useful for professional meteorologists and instructive for amateurs and beginners. Mr. Bassler's address is 164 Race Street, Cincinnati, Ohio.

Since writing the above note we have learned that the Weather Journal had to be discontinued from lack of patronage. It is much to be regretted.

HUDSON'S BAY.—Lieut. Gordon's recent report to the Government at Ottawa does not make it probable that commerce will ever find a valuable outlet through Hudson's Bay. He went during the summer to the mouth of the straits in the Alert and made his way into the bay only with the greatest difficulty even in August, on account of floating ice. The ice was, however, much later last year than usual; the year before the straits were clear in July. He considers four months the season for navigation on this great body of water and, from his own account, navigation would seem to be rather hazardous during these months. The ice is not the only difficulty; the fogs are very frequent and very dense.

The Canadian government has shown much enterprise in ascertaining the capabilities of the bay. It sent an expedition there in 1884, and another in 1885. It has besides observing stations on both shores of the straits and on two of the islands in it for ascertaining the dates of opening and closing. The stations are to be continued next year but Lieut. Gordon's report has about put an end to the idea that a practicable commercial outlet can be found in that quarter.

DEW.—It is curious to notice how opinion occasionally swings back to theories which have been disproved in the opinion of their contemporaries, and have remained unacceptable for scores of years or centuries. Nearly seventy years ago, Wells attacked the then current theory that dew comes from the ground and laid it to rest for the interval from that time to this. Now comes a Scotch investigator, Mr. Aitken, who has been notably

successful in other directions, and revives with every appearance of being right, the old theory of the terrestrial origin of dew. He finds that when a tray is placed upside down on the ground at night the surface toward the ground is copiously dewed, even when the surface exposed to the sky is dry; also that a mass of soil, left in connection with the ground, loses in weight when dew is forming; and that the soil is usually warmer than the air above. These facts are true over soil as well as over grass, and, even on dry roads, the under surface of a slate was copiously bedewed. As a result of numerous experiments Mr. Aitken concludes that the dew is condensed from vapor rising from the soil, thus reviving the opinion of most students of the subject of the last century. Even Wells acknowledged that this happened sometimes.

Mr. Aitken also discusses the origin of the drops found clinging to the apex of grass leaves and to the points and edges of other leaves on a dewy morning. Some of these drops have long been known to be excuded by the leaves themselves. Mr. Aitken concludes that they generally have that origin and finds that they may form in air which is not saturated. If this is the case they should have other constituents than pure water, such as gum or mucilage; a chemical examination of them would add something to the argument.

The dew is in some countries of surpassing importance,—in all probably more important than the study put on it would indicate. In Palestine they are in the season so heavy that they, says Wilson, penetrate the tent and wet everything in it. (The revived old theory would probably deny that they penetrated the tent.) On the plains of Southern Texas, they are also very heavy, especially along the Rio Grande. This was reported by Lewis and Clarke early in the century, who said that they had the effect of refreshing showers. In the region from Natchitoches toward San Antonio, according to them, the richest crops are procured without rain. The soil is spongy, tender, and rich, and seems always to retain humidity sufficient, "with the bounteous dews of heaven," to bring crops to maturity. In conversation the present writer has learned that these dews are even more re-

markable across the Rio Grande, on the Mexican side. Heavy dews are, however, not universal over the southwestern dry region. They are, for instance, light and rare at Santa Fe, but copious twenty-five miles south at both greater and less elevations.

It is curious that dew-bows are not more often seen. The writer has never noted them and he knows of only one record of them. That is of an observation by Professor Rankine, seen in 1862 and recorded in the Philosophical Magazine. It was a spectral iris of hyperbolic form and was seen on a by-road and the less trodden parts of a turnpike a little after noon on a day the forenoon of which had been misty. Its colors were complete and very bright where the road was most moist; it disappeared where there was a sheet of water and was not seen in the grass or the sky.

RAINFALL AND FIRES.—Analysis shows that during the six months having the smallest rainfalls four per cent. more fires occurred than during the months having larger rainfalls. Moreover, the losses during the former period exceeded by seventeen per cent. the losses during the second period, which obviously demonstrates that fires are both more numerous and more destructive during a dry epoch than during a moist one. If a similar comparison be made in the sections for which meteorological reports are regularly issued, it will be observed that the fire losses by seasons follow inversely the inches of rainfall in eight cases out of ten. Thus the average loss by seasons in the middle Atlantic states, in California, in the south Atlantic states, and in the northwest, has uniformly followed the average rainfall. In other sections now and then an exception has occurred, but apparently this fundamental law holds true, viz.: *Other things being equal, the fire loss of a locality for any considerable period varies inversely with the rainfall.* The larger the area and the longer the period covered, with the more certainty and accuracy can this influence be traced.—*Chronicle Fire Tables*, 1886.

REVIEW OF EUROPEAN WEATHER FOR FEBRUARY.—*Barometric*

pressure—From the 1st till the 3rd there is a low pressure over the North Sea causing considerable precipitation in its vicinity, but on the 4th, one minimum recedes in the North, while the other descends to Italy. A high pressure appears in the West. Frost is by this time general as far West as Britain. The maximum just mentioned spreads over the whole of Europe while depressions travel over North Scandinavia, causing high temperature and rain in their vicinity. On the 11th a low pressure appears in the N. W., the influence of which is felt over Britain and Scandinavia. It recedes however on the 15th, while another appears over the Gulf of Biscay. High pressure is now general as far North as North Scandinavia, and as far South as the Mediterranean. A slight depression in the West recedes on the 1st, and high pressure with continual frost as far West as Ireland is general till the end of the month. The latter being remarkable for the very high mean of the barometric pressures, very much above the normal.

Temperature—The temperature of Central Europe was abnormally low and considerably below the normal the mean being almost everywhere below that of January; it is remarkable, not for its severity but for its long duration.

Germany—Above the mean, 1-4; below the mean, 5-28; lowest, 0° at Königsberg on the 27th, highest 42° on the 1st at Altkirch.

Ireland, Valentia.—Above the mean, 1-3, 15-12, 20, 21, 28; below the mean, 4, 13-11, 22-27; lowest, 33° on the 15th; highest, 52° on the 8th.

Sweden, Stockholm.—Above the mean, 1-5, 9-23; below the mean, 6-8, 24-28; lowest, 5° on the 28th; highest, 35° on the 3rd.

Russia, St. Petersburg.—Above the mean, 2-3, 9-16, 28; below the mean, 1, 4-8, 17-27; lowest on the 24th, 8°; highest, 34° on the 9th.

Lapland, Haporanda.—Above the mean, 1-5, 8-16, 18, 11, 21; below the mean, 6, 7, 17, 20-25, 27-28; lowest, 18° on the 24th; highest, 39° on the 10th.

Royal Meteorological Society.—The usual monthly meeting of this Society was held on Wednesday evening, 17th of April.

at the Institution of Civil Engineers, Mr. W. Ellis, F. R. A. S. President in the Chair.

Mr. W. E. Addison, Mr. A. W. Clayden, M. A., F. G. S., Mr. T. B. Moody, R. N., and Dr. W. Schlich, were balloted for and duly elected Fellows of the Society.

The President gave a historical sketch of the barometer. After remarking on the accidental nature of the discovery of the instrument, in the year 1643, in its best form, in ignorance for some time of its value for purposes of meteorological inquiry, he gave a brief account of many early kinds of barometers, the first endeavor being in consequence of difficulties experienced with the ordinary mercurial form, to enlarge the scale of variation attempts which, in general, introduced other errors and inconveniences. The desire to experiment on elevated positions induced the construction of an early form of portable barometer, one such with cistern completely closed leaving the air to communicate through the pores of the wood having been made above 200 years ago. The President further described various points in the arrangement of the Ramsden, Gay Lussac, and other barometers, including also mention of some modern patterns of long range barometers, standard barometers, and such barometers as are more commonly used. The practice of driving out air from the mercury by heating or boiling appear to have been in use early in the last century. Engraved plates indicating the weather to be expected with different heights of the mercury have been longer used, at least as early as 1688. As regards correction for temperature De Luc in the last century adopted a temperature corresponding to 54.°5 F. as that to which to make reduction because corresponding nearly to the average of observations, such reduction being now made to the natural zero 32° F. Reference was made to the employment of water (as in the well-known Royal Society barometer) and other liquids instead of mercury, also to various kinds of floating and other barometers not at all or not entirely mercurial, and to metallic barometers. The President concluded his account with a sketch of the history of recording barometers or barographs, including a notice of the application of photography and electricity to recording purposes.

At the conclusion of the President's address the meeting was adjourned to afford the Fellows and their friends an opportunity of inspecting the valuable and interesting exhibition of barometers which was opened on Tuesday evening.

SCHOTT'S RAINFALL TABLES, 1872.—Mr. Symons, in his *Meteorological Magazine*, calls attention to an error in these tables of which those who employ them should be warned. The abstract for 1848–52, quoted as having been made in York County, New Brunswick, was really made at Thurston, near Dunbar, Haddingtonshire, Scotland. They were begun by Mr. R. Mossman. The error is, as Mr. Symons characterizes it, droll, and leads one to suspect malicious mischief on the part of some clerk.

NATURAL PRESERVATION.—The preservation of perishable objects in dry climates is well known and to be expected. On the dry plains of the southwest a dead ox frequently simply dries up with little putrefaction and such natural mummies are often seen by the traveller at the side of the railroad. A more remarkable and unexpected case is that of natural drying in a wet climate.

This happens on the Aleutian islands. The natives, after a large catch of salmon, in the spring when the salmon run up the streams, simply clean them and hang them up in open sheds, to be left there until wanted. They undergo a sort of drying, though never very dry, and are perfectly preserved. The same thing happens in a more remarkable case. The ancient Aleutians, before being christianized, preserved at least some of their dead as mummies. The bodies underwent a rude preparation, of which soaking was an important part. They were then placed in characteristic attitudes, as throwing the harpoon, sewing, etc., placed in caves with the corresponding utensils, wooden images of whales, skins for sewing, etc., and left. When discovered, half a century or more afterwards, these mummies are dry; they gradually fall to pieces but not by putrefaction.

The same thing happens in the corresponding part of South America,—in the Archipelago to the south of Chiloe. In Commodore Byron's "Narrative" of adventures on the coast of Pata-

gonia (2d ed. p. 90) is related the discovery of a cave in which were many bodies dry and hard.

Yet these two places (the Aleutian Islands and the islands of South Chili) are among the wettest on the globe, not so much in the amount of precipitation as in the humidity. On the Aleutian islands it is nearly always foggy, misty, sleety, or rainy. Commodore Byron complains that, on the coast of Patagonia, they did not for months have a dry thread of clothing on them.

A very different result is seen in some other wet climates. Panama is on the same coast but it is warm as well as wet. The result is that there one of the greatest pests of the resident is made by the lower forms of organic life. Not only is putrefaction certain and prompt, but it is almost impossible to keep molds away from objects which are scrupulously cared for. I one time went with a companion who wished a pair of shoes, to a shoe store in Panama. The shoes were separately wrapped and boxed, yet all were richly sown with mold.

It is an instructive fact that, while lying in harbors in the Aleutian islands, mould forms in the lockers on ship-board and may prove very destructive if one's goods are not carefully watched. The pursuits of a botanist are there accompanied with the serious difficulty that it is almost impossible to dry plants; they become promptly mouldy, thus requiring unceasing care. May it not be that in these high latitudes (about 45° S. and 50° to 55° N.) the small bacterial forms of life are not abundant and that the phenomenon mentioned above is rather due to their absence than to natural drying? It may be that even the molds are not abundant and those found on shipboard were brought from warmer latitudes.

LEEWARD AND WINDWARD WEATHER IN SANDWICH ISLANDS.—The annual reports of the U. S. geological survey usually contain much of interest to meteorologists, and, of course, very much of geographical interest. In the fourth annual report is a very interesting account of a visit by Capt. Dutton to the Sandwich Islands to study their volcanoes. The entire paper, (occupying 144 large pages and making a good sized octavo book of itself), is written

in so plain and simple a manner as to be well within the reach of the general public. It is all of interest, but the writer will quote from it only a note or two on an interesting feature of the climate of the islands. As they lie within the northeast trades and are mountainous, the phenomena of windward and leeward weather are well exemplified. To describe them here I can not do better than to use the author's own words.

"The climate of the islands presents considerations of very great interest. It is difficult to find anywhere greater constancy of atmospheric conditions than those prevailing over the ocean within the heart of the trade-wind belt. The temperature varies but little from winter to summer, and the general drift of the atmosphere is rarely interfered with by storms and cyclones. And yet upon the islands themselves it may be said that there are almost as many climates as there are square leagues. The differences of climatal condition exhibited by localities separated only half a dozen miles are extreme. As a general rule the windward sides are excessively rainy, the precipitation frequently exceeding 200 inches in a year. The leeward sides are generally arid, but to this there are some striking exceptions, especially under the lee of Mauna Loa, where the rainfall is almost as great as on the weather wide. The explanation of this apparent anomaly is interesting. In ascending the lofty domes of Mauna Loa we find that above 10,000 feet or even above 8,000 feet the trade-wind is no longer felt, however strongly or steadily it may be blowing below. Still higher, at 12,000 to 13,000 feet, we find the drift of the atmosphere to be in the opposite direction; this fact is rendered visible below by watching the drift of the clouds. The trade-wind clouds, which hang low, sail ever to the southwestward, while the higher cirrus and stratus float almost in the opposite direction. Whenever the land barrier is low enough to permit the trade-wind to blow over it the lee of the barrier is invariably dry, and sometimes is as parched and barren as the sage plains of the Rocky Mountains. The winds throw down their moisture copiously as they rise to the dividing crest, and descend hot and dry, But when the barrier is lofty enough to effectually oppose the drift of the air the

lee becomes subject to the simple alternations of daily land and sea breeze. As the sea breeze comes in and ascends the slope it sends down rain. As the land breeze floats downward and outward it is dry and clear. The sea breeze sets in a little before noon, and the land breeze goes out a little before midnight. Relatively to human comfort the climate is perfection. It is never hot, and at moderate altitudes it is never cold. The heat of summer is never sufficient to bring lassitude, and labor out of doors is far more tolerable than in the summer of New England or Minnesota. The air is health itself. Pestilential diseases are unknown, and indeed there is no disease of a local character, or which may be regarded as having any special development in the islands, except syphilis and a closely allied form of leprosy to which the native race is exceptionally susceptible."

The author in his journeys over Hawaii finds frequent occasion to return to and insist on these views, and often calls attention to the sharpness of the dividing line between the wet and dry climates. The phenomena described are, many of them, of the character of the foehn in Switzerland and the chinook winds in the west. The foehn phenomena are already known in Pyrenees, about the Caspian, and in Greenland and New Zealand. We must now add the Sandwich Islands to the list.

THE MOUNTAIN METEOROLOGICAL STATIONS OF EUROPE.

A. LAWRENCE ROTCH, S. B.,
Member of the German Meteorological Society and fellow of the Royal (British) Meteorological Society.

GREAT BRITAIN.

Ben Nevis.

Notwithstanding the advanced state of meteorology in Great Britain, it was not until recently that a single high-level station existed in the British Isles, and it is to the Scotch that the establishment of this observatory is due. The following information was gained by a visit to the Ben Nevis Observatory in October, 1885, through the courtesy of Mr. Omond, the superintendent, and Mr. Buchan, the able secretary of the Scottish

Meteorological Society. In comparison with previous data it should be remembered that the following is expressed in English units.

Ben Nevis, in Lat. 56° 48′ N., Lon. 5° 8′ W., on the west coast of Scotland is the highest mountain in Great Britain. It rises 4,400 feet above the arm of the sea, only four miles distant, on which is the town of Fort William. There are, however, large tracts of land between it and the open sea some 40 miles away, and several mountains exceeding 2,000 feet in height.

Meteorological Station.—In 1877 Mr. Milne Home, Chairman of the Council of the Scottish Meteorological Society, drew attention to the advantages of Ben Nevis as a high-level station, embracing the fact that it is in the track of the southwest storms from the Atlantic which exercise such an important influence, especially in winter, upon the weather of Europe. For these reasons the Society determined to erect a permanent observatory upon the top of Ben Nevis, and plans were prepared in 1879 by Mr. Thos. Stevenson, but want of funds prevented any further action then. During the summer of 1881 daily ascents of Ben Nevis were made by Mr. C. L. Wragge and simultaneous observations taken on top and at Fort Williams. These observations were continued during the summers of 1882 and 1883 on a more extended scale with eight intermediate stations. The expense of £570 was met partly by the Scottish Meteorological Society and partly by other grants.

In 1883 subscriptions were opened for the construction of a permanent observatory on Ben Nevis and after £5,000 had been raised, an acre of ground was obtained upon the highest point and a bridle path leading from the farm of Achintee in Glen Nevis, two miles from Fort Williams, was built at a cost of £800. This path, about six feet wide, has a length of five miles with a grade nowhere exceeding 1 in 5. Seven wooden bridges carry it over the streams. It is impracticable for vehicles, owing to the sharp turns, and everything must be carried up on the backs of horses. The telegraph line to the summit was built by the government, and from Achintee is a cable laid in a trench directly up the mountain side. The top of the mountain pre-

sents a large extent of level, or slightly undulating, ground covered with broken rock. For meteorological purposes it is, in fact rather too flat, and must to some degree influence the temperature and wind. The observatory, designed by Mr. S. Mitchell, was formally opened October 17, 1883, and the hourly observations begun by Mr. R. T. Omond and his two assistants on November 24th of that year, have been continued since, without interruption. The observatory, a one story stone structure, stands to the south of the cairn which marks the highest point, the cistern of the barometer (4,407 ft.) being, in fact, only one foot higher than this. As the observatory has recently been enlarged to double its former size by the addition of five new rooms and a tower, the ground plan is somewhat irregular. There are now seven living rooms, besides those in the tower, and one for the use of visitors. The kitchen, formerly used as an office also, is about ten feet square. Opening from it are two bed-rooms about 6x8 feet, the store-room, etc. Raised two steps above the kitchen is the new office, 13x15 feet, from which lead two other bed-rooms 9x7 feet, and the tower on the southeast. This is a circular wooden structure eight feet in diameter, rising some twelve feet above the flat roof of the observatory and twenty-five feet above the ground. It rests upon a stone foundation, having the shape of a truncated cone. Like all the walls, this is laid up dry, having a thickness of ten feet at the base, while the other walls vary from three to four feet in thickness. Within the walls is an air space, then a board casing, and between this and the inner sheathing is a layer of felt. In the new portion, the wooden frame was built first and the felting is on the outside of it. The flat roof is covered with lead upon which are laid spars, and tarpaulin is lashed over the whole. The windows are small and flare outwards, and the panes are double. The building is heated by the kitchen range and by a stove in the office. Paraffine coke, because of its lightness, is the fuel used. Over one hundred pounds are burned daily, and the year's supply of fifteen tons is brought up in summer. A neighboring well then supplies the water, which in winter is had by melting snow and frost-work. The tower has a lightning rod

grounded in clay and terminating in a cluster of points, and though thunder-storms are very rare, brushes of St. Elmo's fire are sometimes seen on the points.

Direct, or "eye," observation of pressure, temperature, humidity, wind direction and force, precipitation, clouds and sunshine are made hourly, day and night, and the series has only been broken by a storm which rendered it impossible to go out of doors. There are two Fortin barometers, made by Negretti and Zambra, one being a spare instrument. They are inclosed in glass cases to keep the temperature as constant as possible. According to the special instructions, this is to be kept as near 57° F. as possible, and the rate of change is not to exceed one degree per hour. If the observation is made more than one minute late, the delay is to be recorded. The readings are not reduced to sea level. A Richard barograph can be used for interpolation if necessary. The thermometers are placed in a Stevenson screen at a considerable distance southeast of the observatory. In winter the screen 14x9x6 inches is fixed on a sort of vertical ladder upon which it can be raised as the depth of snow increases. In summer a larger screen, four feet from the ground, is employed. The ordinary thermometers of Adie and Wedderburn, of Edinburg, were employed, the Negretti and Zambra maximum being disabled, at the time of the writer's visit. The maximum and minimum thermometers are ordinarily read and set at 9 P. M. There is a Richard thermograph, but the dampness spoils the paper, and a solar radiation thermometer, with black bulb in vacuo, cannot be used in cold weather on account of the formation of frost-work on the bulb and the consequent danger of breakage in removing it. The humidity is calculated from the readings of the wet and dry bulbs, except for very low temperatures, when Prof. Chrystal's condensation hygrometer is used. This is a polished metallic box in which is a thermometer. Two rubber tubes admit warm water, or water cooled by snow and salt, so that the box is soon brought to the dew point.

Some difficulty is experienced in using Glaisher's tables which are calculated only for a pressure of 30 inches. A sheet of Negretti and Zambra's ozone paper is placed in the thermometer

screen at 9 A. M. and 9 P. M., and the discoloration in the twelve hours estimated on a scale of 10.

The rain and snow gauges are of copper, five inches in diameter, with hemispherical bottoms that they may be easily leveled in the snow. Each hour a fresh gauge is put out, the exposed one brought in-doors, and the melted snow or rain, if any, measured in a glass graduated to indicate thousandths of an inch. There are several posts with scales of inches on them in the vicinity for measuring the depth of the snow on the ground. If this is much drifted the mean of several measurements is taken. About six feet above the tower is a wind vane registering inside the direction of the wind on a cylinder after the manner of Dr. Draper's anemoscope, except that the marking is done in pencil instead of ink. A Robinson anemometer is connected by a flexible shaft with a revolution counter which is read hourly. The velocity is computed on the principle that 236.8 × constant 2.841 1 mile, and a table obviates calculation. These instruments last October were completely incrusted with ice and snow, and can seldom be used except in summer. From October, 1884, to June, 1885, there were but 30 days when the anemometer was working. The force and direction of the wind each hour are estimated, the former on a scale of 12, the latter to 16 points, the observer standing on the roof for the purpose. Much attention has been given by Mr. Omond to secure uniform estimates of force by all his staff. Upon the roof, often resting upon snow, is a Campbell-Stokes sunshine recorder. The amount of bright sunshine in minutes in each hour is recorded. Several times a day observations always by the same observer, are made with a small Hilger rair band spectroscope. The scale used is from 0 to 7, the rain-band being compared with the E, b and F lines of the spectrum, to which the values 2, 4 and 7 are given respectively, as suggested by Mr. H. R. Mill. The instrument is pointed at an angle of 45° towards the southwest. The character and varying color of fog is noted and a distinction is made between fog (dry) and mist (wet), which latter occurs chiefly in summer. The intensity of the hydrometors is indicated by the exponents 0 to 2, this and the other symbols used during those

adopted by the Vienna Congress. Owing to the number of coronæ glories, etc., seen here Prof. Tait has devised an instrument for measuring their angular size, consisting of a brass rod, graduated to inches, and having a sliding cross piece with three sights. In practice the cross piece is placed at such a distance from the eye that the two outer points cut the circumference to be measured while the middle one coincides with its centre. By referring the number of inches to a table the angular size is at once determined. As yet no means of testing the atmospheric electricity on Ben Nevis has been devised. The great difficulty with all the instruments that require to be exposed to the weather freely is to keep them clear of the almost continual fog or mist.

The day of twenty-four hours is divided into watches of eight hours at night and four during the day, so that there is always one observer keeping watch over the weather, and going out punctually each hour to take the observations. These are recorded in pencil upon printed forms held by an elastic in a cover. At the end of the day they are copied upon a sheet which is manifolded by carbon paper. One copy goes to the Scottish Meteorological Society, another to the London Meteorological Office, while the original is kept at the Observatory. The 9 A. M. and 9 P. M. observations of the chief elements, the wind scale for convenience of transmission being given on a 6-part scale, together with a summary of the day's weather, are telegraphed each evening to the London *Times* and to three Edinburgh and Glasgow newspapers, which pay the cost of telegraphing the report and publish it in the next morning's issue. Telegrams are sent to the London Meteorological Office only when the condition of the weather warrants them, and according to the report of that office for 1884, it has not been found that the special telegrams from Ben Nevis have given earlier intimation of the approach of storms than has been obtained from the other telegraphic reporting stations. At the end of the month separate tabulations are made for the pressure, temperature, humidity, force of wind, direction of wind (obtained by integration and corrected for velocity) and precipitation.

The daily means are computed from the hourly observations and also the means for the same hour of each day, and the mean of each series, which is the monthly mean, should agree. One copy of this sheet is kept at the Observatory and another is sent to Edinburgh.

During the past summer the following experimental work has been done. A wind pressure gauge consisting of eight Robinson cups which are resisted in turning by four springs, and the torsion registered on a revolving drum, the invention of Profs. Chrystal and Crum Brown, was tried at the Marine Station at Granton, with a view to its employment on Ben Nevis. Prof. Ewing made arrangements there for the observation of earthquakes and earth movements by apparatus placed in the lower story of the tower. Prof. Vernon Harcourt and Mr. Harold Dickson spent some time conducting experiments and observations on the intensity of the light in flames under low pressures. Mr. H. N. Dickson carried out under Prof. Tait and Mr. Buchan a series of experiments on methods of obtaining the temperature and humidity of the air. The season was very suitable, on account of the extremes of temperature and humidity. Though the atmosphere was often saturated through a wide range of temperature, cases of excessive and protracted dryness occurred. In September no deposition of dew took place on Prof. Chrystal's hygrometer, though the temperature was lowered to 9°. These exceptionally arid states of the air are of interest in their relations to the unprecedentedly early frosts which occurred over extensive breadths of country in September.

The annual cost of maintaining the Observatory is about £750, towards which a grant of £100 is obtained from the Meteorological Office and the remainder is made up by the Scottish Meteorological Society, and by subscriptions. The total expenditure up to June 30, 1885, was £6,400. The telegraph is rented from the government for £130 annually, three pence being allowed for each telegram sent by tourists. To defray the expense of keeping the road in repair a toll of a shilling is levied on each passenger. A horse cannot haul more than two hundred weight, and costs with the driver seventeen shillings a day. The staff con-

sists of Mr. Omond, the superintendent, and two assistants, one of whom acts as cook. A mail carrier, who also cares for the road, makes the ascent daily in summer and about twice a month in winter. The salaries vary from £250 to £40.

The Fort William Station.—Simultaneous observations are made at Fort William at 8 and 9 A. M., 2, 6 and 9 P. M. The station is close to the sea and only 36 feet above it, giving a difference of elevation between it and the Ben Nevis Observatory of 4,371 feet in a horizontal distance of about four miles. The station seems to be well managed by a schoolmaster. Besides a Kew barometer there is a Richard barograph. The usual thermometers, together with a Richard thermograph, are exposed in a Stevenson screen. The rain gauge is five inches in diameter. The wind direction and force and the clouds are noted and estimations made of ozone and the amount of bright sunshine. The observations have been made since December, 1883, and have been published in the *Journal of the Scot. Met. Soc.* in connection with the observations on Ben Nevis, for which normals have thus been calculated.

Results of Observations.—The observations have not been published *in extenso.* Mr. Omond writes that the later observations are ready to be published but that lack of funds prevents. Mr. Buchan has published the means and discussed the observations in the *Journal of the Scot. Met. Soc.* for 1883 and 1884. The following is a summary for the year ending May 31, 1885. The mean barometer was 25.272 in. and the range 2.145 in. The diurnal barometric curves show a double maximum and minimum for each of the seasons. The afternoon minimum is, in each case, smaller than the morning minimum, as happens on all mountains which rise considerably above the plains surrounding them. The first maximum occurs about noon and the second late in the evening, depending somewhat on the seasons. As the summer advances the barometric curve tends towards a single diurnal maximum and minimum. The mean temperature was 30.6° F. or 0.3° below the calculated normal temperature which, as computed by Mr. Buchan (*Journal Scot. Met. Soc.*, 1883) from the Fort William observations is 30.9°, the monthly minimum being

22.0° in February, and the maximum 41.3° in July. The difference between the mean annual temperatures at Fort William and on Ben Nevis is 16.3°, and as regards the months, the greatest difference is 18.0° in April and the least, 14.9° in December. This gives a diminution of temperature with height of 1° F. for 270 feet on the mean of the year, the most rapid diminution of temperature being 1° for 245 feet in April and the least 296 feet in December. There have been some inversions of temperature noted. Thus on December 31, 1883, the temperature of the air was 4.5° higher on Ben Nevis than at Fort William, the normal difference for this time being 16.0° lower. This relatively high temperature was accompanied by the low relative humidity of 33 per cent. Later observations show that it is when the mountain is within, or on the confines of, an anti-cyclonic area that its temperature relative to that of Fort William is extraordinarily high, and is characterized at the same time by great dryness, while the usual state of the atmosphere is complete saturation. The highest temperature was 60.1° in August, which is the highest ever recorded, and the lowest 11.1° in February. The minimum temperatures have not been very low, the lowest previously recorded having been 9.9°, making the total range of temperature 50.2°. The coldest month was March, with a mean of 22.3°, and the warmest August, with 42.3°.

The number of hours of sunshine for the year was 464, or only 11 per cent. of the possible sunshine. Very heavy rainfalls are of frequent occurrence, 1.30 inches having fallen in an hour and 4.26 inches in a day. The annual precipitation is about 146 inches, which is the largest, so far as known, of any place in North Britain. During the summer months of three years the mean fall on the Ben was nearly double that at Fort William. As nearly the whole precipitation during the other months is snow or hail, a comparison with the rainfall at Fort William for these months is not possible. Snow falls on Ben Nevis every month in the year and in winter reaches a depth of 10 or 12 feet. On May 3, 1885, it was over 10 feet deep. This all disappears from the rocks around the Observatory in midsummer, but by October 6 of last year it had again accumulated to a level depth

of two and a half feet and had drifted so as to cover the windows and obliterate the path. There is another form of precipitation due to the deposition of snow crystals formed from fog upon the windward side of objects when the temperature is below freezing. The rate of growth varies with the density of the fog and the velocity of the mind. According to some experiments of Mr. Omond (*Journal Scot. Met. Soc.*, 1884) the rate of increase was one and one-fourth inch per hour with dense fog and strong wind, so that the frostwork may accumulate to an enormous amount.

The mean velocity of the wind by estimation has been found to decrease from 30 miles an hour in February to 15 miles per hour in May. In each of the months the maximum velocity is during the night and the minimum during the day, being thus the reverse of what occurs at low levels and on plains. The difference between the hour of greatest and the hour of least mean velocity is from four to five miles, the greatest difference occuring in summer. During the winter of 1884–85 a tendency to a double diurnal maximum was indicated. In the short time the anemometer was working, the highest velocity recorded was 81 miles in an hour, while the mean for 12 hours was 74 miles.

CONCLUSION.

In reviewing the study of mountain meteorology in Europe, it will be seen how much has been done by societies and individuals with a very moderate expenditure of money, and that care has been taken, besides obtaining the observations to provide for their publication in a useful form and the discussion of the data. While the United States had the first well equipped mountain station in the world on Mt. Washington, and has still the highest on Pike's Peak, it must be admitted that the results obtained from these stations have been incommensurate with their cost, and that the form of publication of the data adopted in the *Reports of the Chief Signal Officer* is of little use to meteorologists at large. There remains for our state weather services, meteorological societies and mountain clubs an attractive field in the study of mountain meteorology.

THE CAUSES OF ANTI-CYCLONIC COLD IN WINTER.

The general peculiarities of winter weather which accompanies an area of high pressure are excessive cold, peculiar dryness of the air, and calms. These conditions of weather are in direct contrast to those accompanying a centre of low pressure. What then is the cause of the excessive cold observed in anti-cyclonic regions?

In an article entitled "Results derived from an examination of the U. S. Weather Maps for 1872–73,"* Prof. Loomis concluded that the cold, which accompanies a centre of high pressure was due to the descent of a column of air from aloft. By averaging the winds around a centre of high pressure he found that there was an outward movement of the atmosphere from the centre, which would soon cause the barometer to fall unless some other action came in, which he thought was a descent of cold air from aloft. The result of this descent from aloft must, he said, generally cause a fall of temperature on the earth's surface, as the higher air is excessively cold, having lost its heat by radiation. Thus he concluded that in a centre of high pressure the temperature must be below its mean value. By observations, extending over a period of three years, he found that the extremely low temperatures that occur every month, but more particularly in the winter months, were found in the neighborhood of an area of high pressure, and hence were probably connected with the descent of upper air; and he accounted for the long periods of cold weather, that are apt to occur in the winter for ten days or so at a time, by an unusually large area of high pressure.

The only other explanation Prof. Loomis thought plausible, was that the cold was due to a current sweeping along the surface of the earth from the north and naturally bringing a low temperature with it. This he proved to be the normal wind attending a centre of high pressure and so is only a secondary cause of the cold.

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*Vol. IX, American Journal of Science, 1875, p. 12.

In a later paper,* Prof. Loomis says that he finds that facts do not uphold this theory.

In 1876 another theory for the cause of the cold in anti-cyclonic conditions was advanced by Dr. J. Hann. In an article "Ueber des Luftdruck Maximum vom 23 Janner bis 3 Februar, 1876, nebst Bemerkungen uber die Luftdruck Maxima in Al'gemeinen,"† Dr. Hann says: The high temperature and the dryness of air at mountain stations during a barometric maximum is most naturally explained by the descent of air from above, which must produce conditions closely analogous to those of the Foehn. At a certain elevation above the earth's surface, the descending motion must change to a horizontal one, and in this part of its path the air is cooled by radiation, which is extraordinarily favored by the clearness and dryness of the upper air at such times. This strong cooling produces the heavy ground fogs (Bodennebel), which fill then the depressions."

Dr. Hann's theory has been followed by Prof. Davis in an article entitled, "The Cold Island in Michigan."‡ This paper says there are four suggested causes for cold anti-cyclonic weather in the winter months. 1. That it may depend on descent of upper air. 2. That it comes from more northern latitudes in the prevalent north-west winds. 3. That it results from an excess of radiation over insolation. 4. That it results from local evaporation. As regards the first cause, while a current from a moderate height might lower the temperature in summer, any descending current would raise the temperature in winter; and the complete departure of actual winter examples from this theoretic one implies that the control of temperature lies in some other cause. Espy seems to have recognized this earlier than 1841, as is shown by the following extract from the Report of the Academy of Sciences (Paris), on the labors of J. P. Espy concerning tornadoes, etc., reported by Messrs. Arago, Pouillet and Babinet.§ "Finally it is proved by the investiga-

*American Journal of Science. Vol. XX., 1880, p. 12.

†Z. f. M. XI., 1876, p. 129-135.

‡American Meteorological Journal, May, 1885.

§Philosophy of Storms. By James Espy. Boston, 1841. p. 38.

tions of Mr. Espy that it will be impossible hereafter to adduce in the mean state of the atmosphere, a descending current of air as a cause of cold, or an ascending current of dry air as a cause of heat." As regards the second possible cause, that the cold is due to the prevalent north-west winds, the explanation is insufficient, because it simply puts the cause one step farther off. It is a sufficient explanation when winds occur, but the excessive cold of anti-cyclones is found generally during a time of stagnant air; and, indeed, in Europe cases may be named where the temperature was decidedly higher toward the pole than about the centre of high pressure. The cold is therefore of local origin. The third cause explains the cold better. The quiet centre of high pressure approaches the condition of "no atmosphere," that is, the air is so dry and so clear that radiation is retarded the least possible amount. With the air in this condition the rapid radiation through twenty-four hours might more than counterbalance the slow gain of heat by the compression of the air during its gradual descent in the anti-cyclone and by the brief and weak insolation of a winter day. A descending cloudless current, such as occurs in a centre of high pressure, must warm by compression 1.6° F. for every 300 feet of descent; and so unless the temperature aloft is lower than we have any reason to suppose it is, the cold of the lower air must be *in spite of* and not on account of cold aloft. The effect of evaporation, the last cause, is also important. The ground is left moist by the preceding cyclone and vapor is formed rapidly; but it is difficult to measure the effect thus produced.

To make choice among these theories, direct observations of the temperature of the upper air are necessary. What we wish to find is the temperature of the air aloft in a center of high pressure, so that we can compare it with the temperature on the surface. The best means of obtaining these observations of the temperature of the upper air would be by use of a balloon, but such a method is difficult at present, though in the near future the difficulties will probably be overcome. The next best method is to use the observations taken on some mountain top and to compare these with observations taken at a neighboring lower

station. Mt. Washington must be taken, as it is the only mountain station on this coast; but it is a good station on account of the great number of observations taken there at the Signal Service Station, and then, too, it is in the direct path of all our severe storms. To compare with this, Burlington is a good station, as it is not far from the foot of the mountain. Before appealing to observations we may consider, according to the theory of descending currents, what the temperature on top of Mt. Washington would be, compared to that of a lower station, when it is in an area of high pressure and when the air may be considered very dry so that all the work of compression during descent may be devoted to the production of sensible heat. By use of Hertz's "Graphische Methode zur Bestimmung der adiabatischen Zustands-änderungen feuchter Luft,"* we find that the temperature on top of the mountain with the conditions just mentioned should be 33° F. colder than at Burlington. We shall see that such a case is very unusual in winter. Let us take another case going to the other extreme, and supposing the humidity of the upper air to be 100 and so densely clouded that there is evaporation of cloud particles all the way down to the lower station, thus retarding the warming by compression. By use of Hertz's table we find that the temperature on top of Mt. Washington should be 23° F. lower than at Burlington for ordinary winter degrees of cold. This, as has been said, is an extreme case and one that would in all probably *never occur*. Now we may see, if we take this almost impossible case for a true one, how the temperatures actually found by observations will compare with it. By observations extending over four of the winter months of 1872 and 1873† (34 pairs of observations), I find that the average temperature of Mt. Washington, while it was within one hundred miles of the center of high pressure was only 6.6° F. colder than the average temperature of Burlington. This is evidently greatly different from what it should be according to the theory of descending air, and the difference remains to be accounted for.

*Meteorologische Zeitschrift, Nov.—Dec., 1884.

†Signal Service Daily Bulletin of Weather Reports, 1872 and 1873.

The example just cited was for when Mt. Washington was within one hundred miles of the centre of high pressure. From further observations for the same months, when Mt. Washington was within three hundred and fifty miles of the centre, I find the temperature differences to be as follows: For the northern quadrant, *i. e.*, when Mt. Washington was northerly from the centre of high pressure, Mt. Washington was 9° F. colder than Burlington. In the same way the eastern quadrant shows a temperature 10° F. colder; the southern quadrant 4.5° F. colder, which is a very small difference; the western quadrant 12.2° F. colder. From these figures we find the average difference of temperature between Mt. Washington and Burlington while within an area of high pressure, to be about 9° F. From similar observations when Mt. Washington and Burlington were near a centre of low pressure, the average difference was 11° F. This shows that an area of high pressure is the least favorable condition for production of lower cold by descent of upper air. Mt. Washington then, when in a centre of high pressure has a temperature several degrees higher than it should have if the temperature of Burlington at the same time depended on the descent of air. In fact there are numerous examples shown from observations, when the temperature on top of mountains in a centre of high pressure during the winter months, is actually higher than the temperature of the lower stations. On Mt. Washington December 26, 1872, the temperature was 16° F., while at Burlington it was —10° F., thus showing that it was warmer on top of the mountain by 26° F. Again from January 17 to 19, 1873, the temperature on Mt. Washington ranged from 1° to 19° F. warmer than at Burlington, while the average of the wind, which is important to notice in order to explain the abnormal condition of the temperature, was only ten miles per hour, a low velocity for Mt. Washington. It is also to be noticed that during the night of the 17th the temperature on Mt. Washington rose 1° F., while at Burlington it fell 5° F., thus showing an increase of warmth with height. Other good examples of this abnormal condition of the atmosphere on top of mountains in the winter season are given from the Alps by Dr. Hann. In a paper enti-

tled "Die Temperaturverhältnisse die österreichischen Alpenländer,"* Dr. Hann gives a very good example. From the 8th to the 10th of January, 1877, the temperature at Schneeberg, a station 4565 feet above the sea, was from 3.6° F. to 14.4° F. higher than the temperature at Vienna, 652 feet above sea level. During this period the air was extremely dry and a calm prevailed at both places. Another interesting point noticed, which proves conclusively that the air is warmed by some cause independent of diurnal period, was that the temperature on the mountain, during the calm night of the 9th, increased 11.4° F. more than at the lower station, and the only known cause is that the air comes from above. Another good example of this abnormal condition of atmosphere found on mountain tops in winter months is found in a paper on the "Meteorology of Ben Nevis,"† by Buchan. On December 31, 1883, at 11 A. M., the temperature at Fort William, a station at the foot of the mountain on the sea shore, was 27.5° F., while at the same time on top of the mountain the temperature was 32° F., thus showing a greater warmth on top of the mountain by 4.5° F. This condition lasted for almost six hours. An almost unprecedented dryness accompanied this relatively high temperature. Unfortunately the velocities of the winds at the two stations are not given, so that the example loses some of its force. The normal difference of temperature between the two places is 16° F., and since the temperature was 4.5° F. higher at the top than at the sea level, it follows that the abnormality in the vertical distribution of temperature amounted to 20.5° F. At this time the highest atmospheric pressure ever known on top of the mountain was recorded.

What general conclusions can be drawn from these examples? In the winter months during a centre of high pressure, higher temperatures are often found on mountain tops than occur at lower stations. How shall we account for this? In nearly all cases a small velocity of wind and a great dryness of the air is noticed, so these must have some connection with the abnormal

*Vienna Akad. Sitzb., 1885, XCII., p. 73.

†Journal of the Scottish Meteorological Society, for 1883, p. 9.

distribution of temperature. That this abnormality is not due to the direct effect of the sun is well shown by the fact that the temperature increases sometimes during the night. The theory that the cold observed in anti-cyclonic regions is due to a current of cold air from aloft cannot be correct, as very often it is absolutely warmer aloft than below and the vertical decrease of temperature is always slow for the season and very slow for the supposition that that the air is descending and thus warming. According to figures found by Dr. Hann from observations,* the mean difference of temperature between Mt. Washington and Burlington for the winter months is 0.6°+ F. for every 326 feet (100 metres) ascent or about 19° F. difference between Burlinglington and the top of the mountain. From this it will be seen that the mean difference, while the stations are within an area of high pressure, is much less than the mean difference for the season. So the cause of the cold below and the abnormal warmth above must be accounted for in some other way. Let us now examine the theory that ascribes the cold to radiation. As I have said, the centre of an anti-cyclone approaches the condition of "no atmosphere;" that is, the air is clean, dry and cloudless. This air descends very slowly, so slowly that the earth can cool greatly by radiation, and thus the air close to the earth is cooled too. In this way mechanical warming by compression is overcome. The effect of insolation is small; in fact, the radiation is in such excess that insolation is far overcome. So when the air reaches the lower stations it has not mechanically warmed by compression nearly as much as it would were it not for these peculiar conditions, and thus the small difference in the average temperature of Burlington and Mt. Washington while in a centre of high pressure can be accounted for; thus, too, can we account for the high temperature on mountain tops and the lower temperature of the lower stations.

The Foehn wind, which blows in Switzerland, is a seeming exception to the explanation for the occurrence of cold under descending winds. It was formerly supposed that this wind blew across the Mediterranean Sea from the Desert of Sahara,

*Z. f. M. XI, 1876, p. 86.

bringing its great heat from thence. This is now thought to be erroneous, and the Foehn is supposed to be only a local wind, owing its warmth to local conditions; it descends with such rapidity that the valley ground has little time to control its temperature, and mechanical warming by compression does everything it can to raise its temperature. Its warmth is preserved by its great velocity of descent. If on the peaks of the Alps, over which the Foehn blows, an anti-cyclonic calm should occur, undoubtedly the abnormal conditions observed on other mountain peaks would appear there. Another good example showing that a quick descent of the air brings warmth is found in the account previously quoted of the temperatures at Vienna and Schneeberg. From the 8th to the 10th of January, 1877, while the air was in so stable a condition, there was a calm. After the 10th the wind began to blow and very shortly the condition of the atmosphere became normal again. So it is shown, conclusively, I think, that cases of abnormal temperature on mountain tops and at lower stations in anti-cyclones can be explained by the theory brought forward by Dr. Hann, that the abnormality is due to an excess of the cooling by radiation over the warming by insolation and the compression in a slowly descending mass of air. WM. R. DEWEY.

CAMBRIDGE, MASS., February 18, 1886.

THREE "ICE-STORMS."

The section of country comprising northern and north-eastern Massachusetts, southern New Hampshire, and south-western Maine, was visited three times during the past winter, within a period of four weeks, by storms which from their unusual and remarkable effects have been generally denominated "ice-storms."

In each storm there was a considerable precipitation of sleet and rain, in connection with a temperature so low that the water froze immediately wherever it fell. The coating of ice which was thus formed on the trees, wires, etc., was very considerable and, as we shall see, sufficient to do a vast deal of damage. The phenomena of the storms were observed by the writer at

Newburyport, Essex Co., Mass., a locality which seems to have been very centrally located with reference to each of the three storms.

The first ice-storm occurred on the 19th of January, in connection with a barometric depression which moved eastward on that day from the lake regions, and was central on the Massachusetts coast about 8 P. M. Snow began falling at 6 A. M., changing to rain during the forenoon and continuing thus until about 7 P. M., when it turned to hail, and about 8 P. M. again to snow. The snow continued after 8 o'clock about half an hour, and at 9 the storm had passed, the barometer was rising and the clouds had broken away, revealing the glory of a full moon. The total precipitation was 1.21 inches, most of which was in the form of rain. The temperature of the air at an altitude of about 14 feet from the ground (73 feet above the sea-level) ranged between 18.3° and 33.8° during the storm, the records being 19.0° at 7 A. M., 27.0° at 2 P. M., and 26.3° at 9 P. M. The wind was blowing from the north during the day, shifting to northwest about 8 P. M., and later to west. During the whole day the ice was accumulating on the trees and wires and all other exposed objects, and at night it completely covered each branch, twig, rod, and wire with a coating of ice ranging in thickness from $\frac{1}{8}$ to $\frac{3}{8}$ of an inch. Beside this coating myriads of icicles had formed, and hung from the branches where the water had flowed down a short distance before being solidified. These icicles were generally from two to three inches long, though many were seen which had attained a length of six inches. The weight of the ice was sufficient to bend down many of the pliable limbs to a considerable extent, but few, if any, were broken.

The beauty of the scenery as it was revealed to fortunate beholders by the brilliant moonlight of the late evening was such as to be indelibly impressed upon the minds of all who saw it, but the glory of the landscape when illuminated by the sun of the following day was even more magnificent. The paler moonlight imparted to the scene a pearly lustre, but the radiance of the sun changed the pearls to diamonds. From every direction the myriads of reflected and refracted rays struck the eye of the

beholder as jets of brilliant light. Looking in a direction toward the sun it seemed as though the trees were no longer the ordinary masses of wood and bark, but had become transformed into the most gorgeous crystal formations of a fairy-land, while on either side, at angles of from 80 to 150 degrees from the sun, the crystal sparks were dressed in all the glowing colors of the spectrum.

The unwonted splendor of these sights (and they were continually presented to view by the thousands of trees which grace the streets of the city) was the universal subject of comment and admiration.

Such sights, however, were not destined to last a lifetime, and before another day passed the breath of the south wind touched the ice and it vanished.

As a forcible illustration of the widely different effects produced by the same causes working for different lengths of time, came the second ice-storm. This storm began on the 27th of January and lasted until the 30th. On the morning of the 27th the barometer was high, but falling in advance of the large depression which was slowly moving northward off the Atlantic coast. It fell steadily until the afternoon of the 29th, and then again, after a slight rise, until the night of the 30th-31st. A very fine snow began to fall about 8:45 A. M. on the 27th, soon turning to sleet, which continued most of the day and changed to rain in the evening. The rain continued during the night of the 27th-8th and all the next day, amounting to 1.57 inches at 6:30 P. M. on the latter date. On the 27th the temperature ranged between 26.3° and 31.9°, and on the 28th the three observations showed 31.2°, 33.2° and 32.8°, respectively. Almost every drop of rain that fell on the trees and wires during this period froze where it fell or trickled down a few inches only to be added to the icicles that hung from almost every twig. The telegraph and telephone wires were soon coated with ice varying in diameter from $\frac{3}{4}$ of an inch to $1\frac{1}{4}$ inches, and the trees were incased in an equal thickness.

This enormous additional weight, together with a brisk to high N. E. wind which was blowing, soon had a telling effect on

the overladen boughs, and from an early hour on the morning of the 28th, all day long,—crack! crash!—the smaller branches and the larger limbs fell to the ground throughout the city. The ice storm no longer presented its attractive and beautiful effects, but changed all nature into a scene of ruin and desolation. And yet the worst had not come. With the wind still brisk from the N. E. and N. a slight precipitation of rain and sleet continued through the 29th, and until an early hour on the morning of the 30th, the temperature not having risen above 35°, and having averaged only 31°.4 since the storm began. The work of destruction, although not in as great measure as on the 28th, continued while the precipitation lasted, and when at last it ceased with the arrival of higher temperature on the 30th, scarce a tree throughout the city had passed through the ordeal unharmed. The handsome elm trees, of which the city had been justly proud, were broken off as though some great megatherium had browsed over their tops; the maples were stripped of many of their limbs which had presented a large surface for the ice formation; the branches of many lindens were so thoroughly stripped down as to leave the main trunks better fitted for telegraph poles than to serve for ornament; the ash trees with their sturdy arms enjoyed no immunity from the general devastation and many had the tops of their main branches broken off for a length of 30 feet or more; the catalpa and other ornamental trees were roughly handled, as also were many varieties of fruit trees, especially the peach; but the horse chestnuts, having no small twigs on the ends of their boughs, escaped almost wholly without injury. Sad havoc was played with the net-work of wires that covered the city. Wires so thickly coated with ice as to appear like cables or hawsers were down or falling in almost every street, and only six out of about eighty telephone circuits were left in working order. The electric time and fire alarm circuits were completely demoralized, and communication outside of the city was at times almost cut off.

Some streets were for a time impassable, except to foot passengers, on account of fallen wires and branches, while on others where the branches had been piled up on both sides the appear-

ance was as though a gang of lumbermen had begun operations with the intent of logging the whole street.

Newburyport seemed to be near the centre of the region of greatest destruction, but it was only one of numerous afflicted places as a few subjoined reports from neighboring cities will abundantly show:

"Concord, N. H., January 30.—The storm of the past forty-eight hours has caused great damage throughout the State. The rain, which has been falling at intervals, froze, covering everything with a thick coating of ice. The weight on the fruit and shade trees soon became too great for the branches, breaking them and doing incalculable damage.

Reports received from some of the largest fruit growers in the State say that their orchards are entirely ruined.

The damage to the telegraph and telephone wires has been quite serious, and the linemen have been kept busy looking after trouble in different sections. Several of the wires leading from this city were broken down, and others have been worked with difficulty, but all business has been put through. The railroad trains have been generally late, the ice on the tracks making it extremely difficult to run."

"Worcester, Mass., January 30.—This morning finds things in worse shape than ever on account of the sleet storms of the past few days. Many of the trees, which have been encased in a coating of ice for two days, gave way last night under the terrible and long continued strain. Most of the shade trees are sad wrecks and many of the young trees have lost their top limbs. On High street the elms were so weighted that their lower limbs touched the sidewalk, and compelled pedestrians to take to the street. The telephone lines were never in such bad shape, especially lines leading out of town, which are a complete wreck. The Western Union company reports a wreck at Charlton, on the Albany railroad, where the wire and cross-arms are stripped from the poles for a distance of over a quarter of a mile.

The wires lay in a bunch twisted together and frozen in the ice and snow. The old A. & B. line through Westboro was entirely down. Yesterday repairmen were sent over it who found

it a complete wreck the entire distance. They put the wires in working order, but had scarcely returned when the whole route went down again."

"Portsmouth, N. H., January 30.—The damage caused in Portsmouth by the recent rain is believed to be unparalleled in that line in the history of the place. The ice gathered in masses on trees and shubbery of every description, and the injury is universal. A large gang of city men has been kept at work, and with considerable difficulty has kept the sidewalks clear of falling limbs and trees. Especial injury was done in the South cemetery, on Richards avenue, and on Middle, South, Pleasant, Elm, Islington, State, Daniel and Lyden streets. Hundreds of shade trees were completely ruined, while many whose age and beauty were the pride of the city, have been greatly disfigured by the breaking of limbs."

"Portland, Me., January 30.—The destruction of the noble elm trees that have caused Portland to be named the "Forest City" is greatly deplored by every one, as it has been so general that it will require years to repair the damage.

As one stands at the head of Fore, High, Park, State and Winter streets, and looks down their length, it almost appears as though as large a proportion of the trees have fallen to the ground as have remained in their former upright position. Lincoln Park suffers more, proportionately, than any other locality, because the trees there were young, having all been planted since the great fire in 1866. Many of them are ruined, and others will be sadly disfigured by their loss of large branches.

A mass of cross-bars on telegraph and telephone poles on Commercial street gave way at noon, obstructing the street completely. This is the most serious trouble yet, as hundreds of the wires are crossed and recrossed over the street, making it impossible to run trains from the Grand Trunk to the Eastern, Maine Central, and Boston & Maine depots."

"Haverhill, Mass., January 30.—The damage caused to the shade and fruit trees by the ice storm of the past week is incalculable. Whole orchards in Haverhill and the immediate vicinity are ruined, and the loss to the farmers is immense. The

stately elms which adorn City Hall Park are broken in every direction, and immense branches broken entirely off cover the ground. Some of the suburban roads are absolutely impassable on account of the limbs and branches, and in some cases whole trees lie in the path. The freighters who bring shoes into the city from the adjoining towns of Rockingham county, N. H., tell tales of damage done which seem almost incredible.

In the little town of Chester alone the loss is estimated at $2500."

Such a storm had never before occurred within the memory of any man living, and none of those who saw this one expected to live to see another like it. But they were destined to be disappointed, for on the 11th and 12th of February occurred the third of these now terrible calamities.

The third ice storm began about 5 P. M. on the 11th of February and continued through the night with excessive precipitation in the form of rain, almost every drop of which froze where it fell. The barometer was falling in advance of a storm which was moving northeasterly from Tennessee, and the temperature during the night ranged between 29 and 32 degrees with a brisk N. E. wind. The rain continued during the whole of the following day (the 12th) forming a part of the remarkable "deluge" of that week, but the temperature was such that after 9 A. M. of the 12th no damage occurred from accumulating ice. The night had done its work, however; the ice encased the trees and wires more thickly even than in the second storm, and branch after branch fell crashing to the ground, wire after wire snapped and fell or by its weight pulled down the pole or frame upon which it was fastened. Trees that had undergone the strain of the previous storms were at last forced to succumb, and even the horse chestnuts now lost many large limbs. Scores of elms and maples that had been injured before were now totally ruined, and many a tree was seen split to the ground and fallen prostrate.

The mass of ice that accumulated on all outdoor objects in this storm is almost incredible, but the instances that are now given are vouched for on excellent authority. A twig 3-16 of an

inch in diameter measured with its covering of ice $1\frac{3}{4}$ inches in diameter. A piece of telephone wire one foot long when found encased in ice weighed 12 *oz.*, but after the ice was removed its weight was $\frac{1}{2}$ oz. Still more remarkable was the revelation in the case of a little twig that had fallen from the N. E. side of an elm tree in a very exposed situation. The twig was about six inches long and was afterward ascertained, by careful weighing on accurate scales to weigh 1-32 of an ounce. This little twig when found with the mass of ice which encased it weighed $15\frac{1}{2}$ oz., or 496 times the weight of the twig alone.

In contemplation of such facts as these the greater wonder is that any portions of the trees beyond the mere trunks withstood the enormous strain and pressure exerted on them.

The damage occasioned by these storms will be painfully obvious during the coming summers and probably cannot be repaired in a generation.

The occurrence of the storms was undoubtedly due to the precipitation of the moisture of the clouds in a warm stratum of air at an elevation above the earth's surface, while the surface stratum was cooled by a northerly or northeasterly current. Observations at Mt. Washington confirm this theory since during the third storm the temperature at the summit of the mountain where it is almost invariably much lower than at any other station in New England, was 31° and 39° at two observations during the storm while at Portland, Me., it was 24° and 37° at the same hours, and at Newburyport, 29° and 37°. After the second and third ice storms the warmer equatorial current prevailed at the surface of the earth before precipitation had ceased, while after the first one it prevailed within forty hours. The question then arises,—What caused the prevalence of this cold current near the surface while there was a warmer current overhead at no great altitude and moving in an opposite direction?

In whatever way this question may be answered the inhabitants of New England are at length willing to forego the pleasure to be derived from the beauties of another ice storm.

F. V. Pike.

FOREIGN STUDIES OF THUNDER-STORMS.

THUNDER-STORMS IN CENTRAL GERMANY.

The systematic observation of thunder-storms in Central Germany was inaugurated by Assman in 1880, when the observers were organized into a society by the name of the "Verein für landwirtschaftliche Wetterkunde." Two hundred correspondents were soon secured, and in 1885 the number had risen to about six hundred. The reports are made on a printed card, addressed to the Verein in Magdeburg, and give especial attention to electrical phenomena. The following notes on the results attained are taken from Dr. Assman's pamphlet "Die Gewitter in Mitteldeutschland" (Halle, 1885), in which the records of self-registering instruments at Magdeburg are given the greatest importance.

The relation of the barometer to thunder-storms is thus expressed; there is first a slow, continuous, but often irregular fall; then with the breaking of the storm, almost coincident with the first thunder, there is a rapid rise of the mercury which sometimes amounts to several millimeters in five or ten minutes; next, after a variable interval of oscillations, the readings rapidly decrease, to be followed at last by a regular increase. A number of self-registering barometric curves are given, in which these peculiarities appear more or less distinctly; the Richard Frères' aneroid-barographs are spoken of highly for such records, and are regarded as entirely trustworthy. On the synoptic weather charts, the barometric depressions accompanying thunder-storms are secondary formations in larger areas of low pressure, and follow the usual course eastward across Europe; they are characterized on the forward side by east or southeast winds and clear sky, thus favoring a considerable rise of temperature; while on the rear the heavy cloudiness retards warming, and further by the descent of air from higher levels brings about a strong contrast of temperature, which on the one hand increases the pressure in the rear and thus steepens the gradients even to the production of thunder-squalls (Gewitterböen), and on the other gives opportunity for the energetic condensation of vapor. The

following conclusions are emphasized. 1°; the short and sudden baric changes stand in causal connection with thunder-storms and heavy rains; the two are to be considered as different forms in the appearance of a single process. 2; not all storms and precipitation are accompanied by baric changes. 3; these changes correspond in most cases to a sharply limited wedge of high pressure that is thrust into the area of the secondary depression.

The wind in thunder-storms veers and backs with equal frequency; and not infrequently reverses its course directly. During the storm the strength of the wind does not vary noticeably, except at the passage of the dusty squalls just before the storm; these are sometimes violent and lift much dust into the air; it is suggested that they may have an ascensional element, in as much as they raise the dust so much more effectually than ordinary winds of the same strength.

As far as the distribution of storms is concerned, their frequency seems uniform over Central Germany.

The cirro-stratus "cover," overlying or spreading out from the storm's cumulus is regarded as an invariable accompaniment of thunder-storms; and is taken as evidence of the whirling nature (Wirbel-Natur) of the whole storm; but its altitude is thought to be less than that of ordinary cirrus clouds.

Thunder-storms have not been observed during the course of this investigation at lower levels than the mountain stations (Brocken, Inselberg, etc.,) although popular account frequently so places them.

Rain is so constant a feature of thunder-storms that the greatest part of the precipitation of continental Europe is of this origin; a single storm may yield a tenth to a fifth of the years fall. A relation between heavy showers and electric discharges during the storm is regarded as proved, and of the two the latter is considered the cause or opportunity for the former. Cloud-bursts occur chiefly on the northern and eastern sides of the mountain ranges, but occasionally in the low lands also. Hail-falls are most frequent in the relatively dry regions on the lee-side of elevations, and are thus related to cloud-bursts. Storms without rain are occasionally recorded; they come after long dry

spells of weather, and seem to be at a greater elevation than usual; the absence of rain-fall can often be accounted for by its dissolving in the dry air under the cloud from which it is seen to fall; at such times the thunder is moderate even with vivid lightning.

As to the dates and times of greatest frequency; July is the month and three to four P. M. the hour of most numerous storms. Whenever, even in the colder months, the temperature rises distinctly above the normal, thunder-storms soon appear. As in Bavaria, a faint secondary maximum of frequency is discovered early in the morning about 1 A. M.

Plates illustrating barometric curves and the relation of storms to temperature and to the hours of the day, and a map of the distribution of hail-storms accompany this report; it closes by a supplement discussing Sohncke's paper in the origin of atmospheric electricity. The same author has written: "Eine lokale Gewittercyklone," *Zeitschrift für Meteorologie*, XVII, 337: Die Gewitter-Bö vom 13 Mai 1884, *Das Wetter*, 17.

THUNDER-STORMS IN SWITZERLAND.

The first report on thunder-storms in Switzerland is for the year 1883, in the *Annalen der Schweizerischen Meteorologischen Central-Anstalt* (Vol. XX, Zurich). Mention is made in the introduction of the variety of data received from observers; some sending in the simplest statements, others making accurate scientific reports in much detail. [This inequality of method is inherent in any volunteer system and can best be reduced by classifying the observers; in this way, those more interested in the subject can be encouraged to carry their work to considerable detail and still follow a systematic plan in accord with others of their class; the essential for success in the work requiring that the same kind of observations shall be made at as many stations as possible in order to obtain comparable results.] The narrative description of separate storms is made by Mantel, and is subdivided according to months; no attempt is made to draw conclusions or to build up theories for the present. Forty-eight small maps of Switzerland present the tracks of storms of

special interest. Motion from southwest to northeast is most common, but several examples are given in which the storms move in the opposite direction; for instance, April 20, south of the Rhine from Lake Constance to Basel; June 6, from Lake Constance to Lake Neuchatel; others appear in which the storm occupies at first a small area, and then expands in nearly all directions, its front lines being sharply bent, almost closed curves; such was the storm of May 7, beginning in the mountains north of Lake Brienz, and spreading with much uniformity northeast, northwest and southwest; again on May 17, a storm began just west of Lake Constance, and after growing east, south and west, continued to the southwest as far as Lake Thun. In several cases the storm front lies about parallel to the Jura mountains, and advances obliquely to the eastward; two such storms are noted on July 13; others on August 4 and 15 advanced to the southeast from a similar beginning. On July 5, there was a storm with a well marked *concave* front that seems to be a very rare type. Very few storms are recorded as stretching a continuous front over the Alps from north to south, but one of this kind appears on July 10, when for a time, perhaps by the blending of two storms, the front extended from Lake Constance on the north, over the mountains, to Lake Como on the south. The paths of hail-falls are in practically all cases directed northeasterly; they maintain their direction over considerable inequalities of the surface, as do many of the smaller storms, thus showing that the control of their advance resides at a great height. [The numerous mountain stations in Switzerland offer fine opportunity for examination of the vertical structure of thunderstorms, to which we shall hope to see due attention paid in future years; the vertical decrease of temperature before and during storms is doubtless the most important element yet to be determined in this investigation, and may be studied to especial advantage in such a country as Switzerland.]

THUNDER-STORMS IN RUSSIA.

At the suggestion of Woeikoff, the Imperial Geographical Society of Russia instituted the special study of thunder-storms

in that country in 1871. The first report on the work that I have seen is a French abstract—Les Orages en Russie (Odessa, 1886)—by Klossovsky, professor at the University of Odessa, from his original memoir of the same title in Russian. The objects of the study at present are: 1st, the geographic distribution of thunder-storm activity and its annual and diurnal periods; 2d, the mutual relation of thunder-storms and the larger cyclonic storms ("areas of low pressure" of our Signal Service; Klossovsky uses *tourbillon, cyclon* and *minimum* as synonymous terms in this sense.)

The number of days in a year on which thunder-storms occur is least in the extreme north, where it falls to 7 or even 3; from Finland, across Central Russia, the number rises from 12 to 21; in the south it falls again to 12 and 6. In the Ural and Caucasus mountains, the average record is 18 and 35 to 40 annually.

The total number of storms varies in successive years, as if a deficiency in one locality was not made up by an excess in anothe. The numbers determined by thirty stations is:

Year	1870	'71	'72	'73	'74	'75	'76	'77	'78	'79
Storms	454	510	715	663	278	410	525	389	420	440

The minimum of 1874 is very strongly marked here.

Storms are almost absent in the winter months, especially in the north. June, July and August furnish the greatest number. An increase in frequency is seen in the warmer areas; and the agreement in the distribution of storms and that of the summer rains shows an intimate relation between the two.

The distribution of storms through the day is such that they begin most commonly in the afternoon, when the temperature and absolute humidity are highest and the relative humidity lowest; they are rarest in the early morning, when these conditions are reversed.

The control over the occurrence of thunder-storms exercised by cyclones is seen in the greater frequency of the former in regions commonly crossed by the latter; but there are other important conditions of control. In the northwest of Europe, where the cyclones continually run ashore from the Atlantic,

local storms are relatively rare, three to nine a year, on account of the moderate temperatures, high relative humidity, and perhaps also because of the prevalence of fogs. A similar poverty is seen along the western coast of Europe; but on penetrating the continent or on turning to the south, the storms become more numerous. In Russia, the thunder-storms appear in a certain limited part of the cyclonic area, generally in the southeast quadrant, or else form a belt around the center; they are absent in anti-cyclonic areas. Thunder-storms of moderate intensity sometimes occur when the atmospheric pressure is nearly uniform over a large region, but in such cases the bending of the isobars indicates that the storms are connected with small secondary depressions. The courses of the larger and the smaller disturbances generally correspond in direction and velocity.

The author rejects Mohn's classification of thunder-storms into *Wärmegewitter* and *Wirbelgewitter*, and refers all to the latter class; warmth alone does not seem sufficient to produce them; else why their rarity about the Caspian and Aral seas. Moreover, in anti-cyclones the sky is clear and insolation intense; these are the conditions needed for the production of unstable equilibrium and strong ascending currents; but these areas are practically free from thunder-storms, as the following table shows:

Pressure in milimeters.....	735 740	740 745	745 750	750 755	755 760	760 765	765 770
Per cent. of thunder-storms.....	0.1	0.3	5.8	37.5	48.3	7.9	0.1
Per cent. of hailstorms.....	0.6	4.6	—	35.5	48.0	11.2	—

From this it is clear that thunder-storms are most frequent on the marginal parts of cyclones, on the frontier between maxima and minima of pressure. The absence of storms in areas of notably low pressure agrees with their rarity in strongly developed cyclones.

Klossovsky concludes that thunder-storms in Russia are in fact small cyclones, originating in the segmentation of the larger storms in the peripheral parts, each segment moving as a whole in accordance with the larger cyclonic circulation. The distribution of the smaller storms in the larger is shown by the

following percentages for the several octants for certain months and for the year; 1416 storms are here represented:

Octant	N	NE	E	SE	S	SW	W	NW
April	0	5.4	7.1	62.5	16.1	8.9	0	0
July	4.2	9.7	9.5	36.4	11.1	18.6	2.3	8.2
Year	2.3	12.6	8.4	41.4	9.5	19.3	1.4	5.1
Year (hail)	—	9.4	6.2	46.9	15.6	15.6	2.1	4.2

It thus appears that the southeastern octant is the one of most numerous thunder-storms in Russia as elsewhere; the limitation to this octant is much more pronounced in April and September than in the warmer months: this is thought to be due in part to the cyclonic circulation and in part to the general rise of temperature to the southeast.

The following table represents (*a*) the direction whence thunder-storms and hail-storms approached, (*b*) the direction of their winds and (*c*) of their clouds, for Russia (omitting the Ural and Siberia, except in the first line) the numbers are percentages:

Thunder-storms.	N	NE	E	SE	S	SW	W	NW	Calm.
a	7 2	6.6	5.4	9.0	14.1	22.7	18.7	16 3	—
b	5	6	7	9	13	24	18	12	6
c	8	8	9	11	14	23	16	10	—
Hail-storms.									
a	7	2	4	8	17	25	24	13	—
b	11	3	5	11	14	24	14	14	4
c	8	5	6	13	14	25	18	11	—

These figures, with those of the two preceding tables, show that thunder-storms and hail-storms agree very closely in the conditions of their distribution; they are therefore phenomena of the same nature; from the preference of tornadoes also for the octant of cyclones occupied by thunder and hail-storms, there would seem to be a relation in the formation of these several kinds of local storms.

THUNDER-STORMS IN INDIA.

Mr. J. Eliot has published a paper on "Storms in Bengal during the Year 1876," in the Indian Meteorological Memoirs (i. 1878, 119–145), which presents the results of observations at a few stations on a class of short-lived storms that he calls "Northwesters." They are manifestly similiar to our more

violent thunder-storms. Six of them occurred between May 26 and June 3, 1877, always between the hours of six and nine in the evening, and all agreeing in presenting the following characteristics: 1st. They are preceded by a rise in the barometer, varying from eight to fifteen hundredths of an inch; this is sometimes strong enough to mask the ordinarily distinct fall in the normal diurnal variation of the barometer. 2nd. With this, there is a very rapid decrease of temperature, usually amounting to ten or twelve degrees F., the greater part of which always occurs very suddenly, being registered by thermographs in less than ten minutes. On May 26, a fall of 11°.9 was registered in ten minutes; the actual fall is probably much faster. 3rd. They produce an equally rapid and simultaneous decrease of fifteen to twenty hundredths of an inch in the pressure of the aqueous vapor. 4th. They cause an almost instantaneous reversal in the wind's direction and a considerable increase in its velocity. The velocity in the violent rush of wind that immediately preceds and ushers in a storm proper occasionally amounts to from forty to sixty miles an hour. The barometer rises before every gust of wind and falls a little while it blows. 5th. These phenomena are generally followed by a shower of rain, which seldom exceeds half an inch. The cloud movement in the storm is complicated and indicates violent and rapid action in the upper air. Further observations are still much needed on this point.

The origin of the gust of cold wind is placed by Eliot in the cold upper return current that is known to exist during the hot season by the movement of high clouds; and the beginning of the rain is ascribed to the mixing of this cold current with the more humid lower air. Eliot recognizes the difficulty of maintaining an appreciable cold in the wind from aloft while compression during descent warms it, and admits that in nearly all cases—apparently including those here considered—a descending current would be raised very decidedly above the temperature of the air around it; still he holds to this explanation, and quotes in its support the occurrence of cool descending winds in northwestern India. The chief interest of this extract in the

present connection is the additional evidence that it gives of the wide-spread occurrence of thunder-squalls, known under various local names. Blanford has a brief note on these Northeasters in his 'Indian Meteorologist's Vade-mecum' (Calcutta, 1877). They consist of heavy cumulus clouds surmounted with a pallio-cirrus; a cold squall blows out from beneath the cloud, raising volumes of dust; hail sometimes falls with the rain. "The storm-cloud is probably in all cases the seat of an ascending correction current, and occasionally the course of the inflowing currents is rendered visible by small tufts of cloud which form in the transparent atmosphere beyond the edges of the storm-cloud and drift into it, when their horizontal motion ceases and they become absorbed." W. M. DAVIS.

The following should be added to the account of the French storms in a previous number of the JOURNAL:

E. Fron. Des orages et de leurs rapports avec les mouvements généraux de l'atmosphére (Ann. Soc. Mét. France, XV, 1867, 95–161). After an introduction on the general features of atmospheric circulation, in which the author follows the theories of Marié-Davy, and a chapter reviewing certain previous studies of thunder-storms, we find the following statements:

The thunder-storms of 1865 are all related to the larger cyclonic storms (bourrasques); they are developed only in the dangerous semi-circle and are carried along by the general winds of this portion of the larger disturbance (137). The same is said for tornadoes (trombes), and their regular right-to-left rotation is ascribed, first, to the rotation of the earth, second, to the rotation of the storm in which they are formed (152).

The other generalizations concerning thunder-storms are like those already given from Fron's reports.

[Copies of THE JOURNAL for May, 1885, are wanted, for which we will pay 25 cents each, and esteem it a favor to any one who will send them.—Manager JOURNAL.]

CORRESPONDENCE.

THE TEMPERATURE OF MEDITERRANEAN SEAS.

To the Editor:—The argument against the high temperature of the earth's interior, drawn by Mr. Bent in his recent letter to the Journal, from the prevailence of low temperatures in the deep ocean waters fails to reach the question when it is remembered that the Mediterranean seas are significant exceptions to the rule. The deep water of enclosed oceanic basins, that are shut in from deep communication with the polar seas, is relatively warm in spite of its depth. Indeed, although generally described as of constant temperature at depths below the deepest passage in their enclosing barrier, we should expect to find the Mediterraneans growing a little warmer towards the bottom, by reason of the heat gained from the earth below. Such a slight increase in warmth would not be detected by the ordinary maximum and minimum thermometers used in deep-sea sounding, but might be obtained by the galvanometer method, employed by Captain Bartlett in his exploration of the Gulf Stream. Can any of your readers inform me if this method has been used in the Mediterranean basins and with what result?

W. M. Davis.

Cambridge, Mass., April 15, 1886.

GROUND OR ANCHOR ICE.

To the Editor:—In our Vermont streams, after a long, still, spell, we often find ice in the bottom of the streams. It is frequently discussed here but no two seem to agree on the same explanation. It is liable to form around mill-wheels, etc., and so give a good deal of trouble. I suppose the question is settled, and I would be obliged if you would inform me of the explanation. S. T. J.

[The phenomenon is so remarkable a one and is withal so common (being found in northern latitudes generally) that it has attracted much attention but can not be said to have yet received an explanation which is entirely satisfactory. One

theory is that the ice is really surface-formed and, driven down by whirls or eddies, adheres to rocks or other free surfaces at the bottom. This could very easily happen, especially in rapid, shallow streams, more especially just beyond a fall; it does actually happen at Sandy Hill, New York.

At the same time there are some facts which do not admit of such an explanation. Müller, in his Cosmic Physics, says that this ice sometimes brings up the anchors of the pontoon bridges of the Rhine, and Steenke claims to have seen the chain of an ice-buoy thus brought up in the harbor of Pillau. Besides, the ground-ice sometimes forms in quiet places as in mountain lakes. In such cases the ice has undoubtedly formed at the bottom, but the mode of formation is not clear. It is well known that ice forms most freely on solid surfaces and projecting points, and this undoubtedly plays a part in the phenomenon. If the bottom were for any reason cooled to below the freezing point the ice might form in the water in contact with the bottom.

Anchor ice has been but little studied in this country. It is found in many streams; the Charles, the Genesee, the Chenango, the Alleghany, even as far south as the James river, I have read of, or heard of, on good authority in this connection. In the Canadian rivers the phenomenon is still more common, and in the Artic the ice sometimes forms very rapidly.—ED.]

MINIMUM TEMPERATURE AT HELENA.

TO THE EDITOR:—According to the observations of the United States Signal Service the temperature at Helena, Montana, fell to *forty degrees below zero* in December, 1880. See report for 1881, page 453. Compare this with AMERICAN METEOROLOGICAL JOURNAL, volume 2, page 532. ELIAS LOOMIS.

[The minimum temperature, on page 532, should be — 36° (thirty-six degrees below zero). The disappearance of the sign — was a typographical error. The difference between — 36° and — 40° is probably partly due to the instruments and partly to differences in elevation and exposure. Helena lies on a gulch running up the mountain side, and the elevations within the city vary very much.—ED.]

LITERARY NOTES.

(1) **Thomas M. Woodruff**, *Cold Waves and their Progress* A preliminary study. Prepared under the direction of Gen. W. B. Hazen, Chief Signal Officer, Signal Service Notes, No. XXII, Washington, 1885, octavo, pp. 21. It is pleasant to have this evidence that the very important "cold waves" are receiving persistent attention. This attention is to be continued, as we learn from this pamphlet that it has been made a special subject of study in the Signal Office, and that another report is now in its archives and will be published in due time.

This pamphlet gives evidence of serious and prolonged study of the phenomena in question, so that it is not the fault of the author if the results give us nothing new nor very precise. Not only does it not give us an idea of the cause and fundamental character of cold waves, but even the resumé of results only confirms us in some general, and not very precise ideas prevalent before. They are remarkable phenomena, associated with high pressures, most common in winter, independent of the daily variations of the meteorological elements, coming for the most part from the high Northwest, associated closely with gales, including the "Northers" of Texas and Mexico, with erratic but often rapid motions, and having some close but unknown relations to areas of low pressure.

There are some suggestions which we might make which seem to have escaped the author. The change in temperature and the wind are in relation to the change in barometer; the more rapidly the barometer rises, the more rapidly the thermometer falls, and the greater is the wind's velocity. With them come the blizzards of Dakota and Manitoba and for a blizzard dry air is one necessity. That the cold waves are usually dry is well known, but it is not always remembered that an essential part of a blizzard is fine dry snow (due to dry air) drifting fiercely and flying thickly with the wind. It is not so much the low temperature or the wind, as it is this flying snow, filling the air and shutting in the wanderer on the prairie, that makes the blizzard so fearful.

Another feature of the paper which is, it seems to the writer, mistaken, is the making of Helena the center from which the cold wave is to be followed. Helena is not in the track of the Northwestern nor of the Southwestern cold waves. She feels them, especially the first, but it is only the edge of them which passes over her. On the ground, in Dakota and Montana, it is believed that the track of the Northwestern ones does not fall west of the *Coteaux*, that is of the dividing ridge between the Missouri river valley, and that of the Mouse river. Western Dakota is already beyond them, and Montana still more so.

These remarks are made rather as suggestions. The writer believes that there are very few special questions in American meteorology the

solution of which is more important than that of the cold waves. They have some relation to our high winds in the Mississippi valley and lake region. The blizzard, the western gales, the northers which extend from Kansas to Panama depend on the cold waves. The climate of the states and territories of the upper Mississippi and of the Red River depend on them. They make some parts of the high Northwest almost uninhabitable. Their careful study is a matter of the highest importance. Indeed, viewing them in their general aspect, they are no longer of local but of universal importance for a solution of their nature means a solution of the nature of areas of high pressure in general. H.

(2) **E. L. Shurly, M. D.** *A Report on the origin and Geographical Distribution of Phthisis Pulmonalis for the State of Michigan. Pam. pp. 15.* A paper read before the American Climatological Association, May 28, 1885, and printed in the New York Medical Journal for November 14, 1885, and reprinted in pamphlet form. In the preparation of this article Dr. Shurly's chief object was, as far as possible to secure, by correspondence, the number of cases of phthisis pulmonalis *originating* in different sections of Michigan, and to investigate the telluric and other conditions effecting its production. The difficulty of obtaining such information anywhere where statistics upon the subject had not already been collected, as is the case in Michigan, is apparent. Dr. Shurly, however, has obtained sufficient data upon the subject to be likely to awaken further interest in its investigation. The topography, hydrography, and geology of the state are quite fully discussed. A. W. N.

(3) **J. B. Trembley, M. D.** *Meteorology of Oakland, California, for 1882-84 and 1883-84.* Oakland, 1884, Octavo, 35 pages. Also sheets containing similar data for 1884, and for 1885. We have already noticed Dr. Trembley's excellent work and hope it is to continue. We regret to see that the neat pamphlet of earlier reports is now replaced by sheets for 1885. It is to be hoped that the pamphlets will still appear as they are much handier. H.

(4) **Lieut. Geo. L. Dyer.** *The Use of Oil to lessen the dangerous Effect of heavy Seas.* Compiled for the monthly Pilot Chart, issued by the United States Hydrographic Office, Commander J. R. Bartlett, U. S. N. Hydrographer, No. 82, Washington, 1886, octavo, 27 pages. We have here, gathered into a pamphlet, the reports of the trials of oil in lessening the dangerous effects of heavy seas, which have been printed from time to time on the Pilot Charts, (some of which have been reprinted in this Journal). They are interesting and suggestive and fully justify the activity of the Hydrographic Office in this direction. The work of collecting these reports is to be continued. The writer is inclined to the opinion that good results could be obtained by laboratory experiments, especially in the way of ascertaining the exact causes of this effect of oils, the best oils to employ, and similar questions. The office reports that experience seems to demonstrate that mineral oils are not so effective as vegetable or animal oils. H.

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